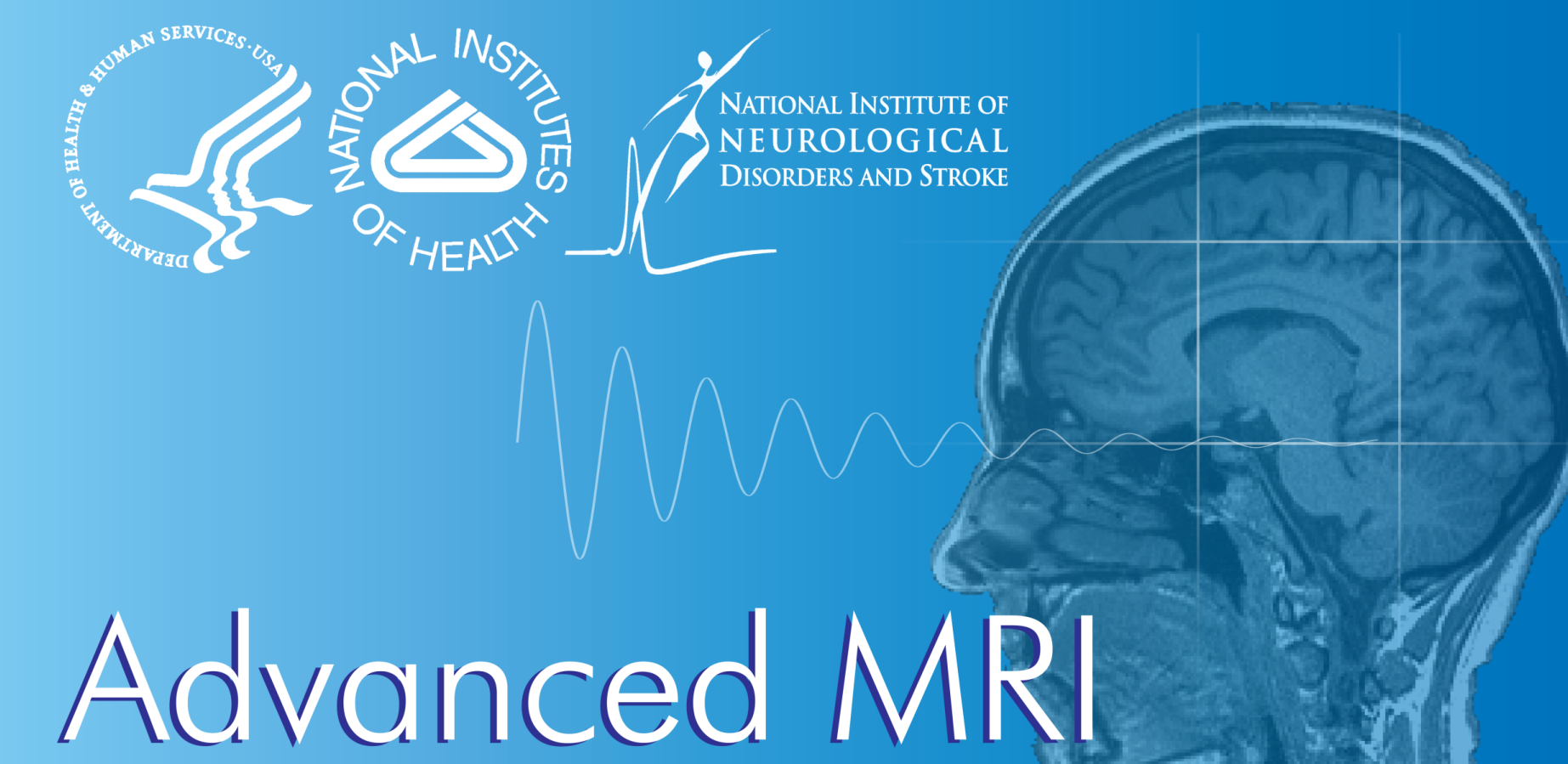


Multi-Component Fitting of T_2^* Relaxation in White Matter at 3 and 7 Tesla

Erika P. Raven^{1,3}, Peter van Gelderen², Xiaozhen Li², Jacco A. de Zwart², John VanMeter³, Jeff H. Duyn²

¹Georgetown University, Washington, DC, United States, ²Advanced MRI, LFMI, NINDS, NIH, Bethesda, MD, United States,

³Georgetown Center for Functional and Molecular Imaging, Washington, DC, United States



Introduction

- High magnetic field strength increases susceptibility contrast in tissue, reflected in increased local resonance frequency shifts (Δf) and R_2^* ($=1/T_2^*$) decay rates.
- Distinctions between different cellular compartments may become more apparent at high field, allowing multi-exponential signal decay fitting to separate signal from the axonal lumen, the interstitial space, and water between the **myelin layers** that surround axons^{1,2}.
- The latter may have important applications for the study of myelin changes in normal aging and with disease.
- This study will attempt to corroborate previous findings at 7T², while investigating the feasibility of extending them to 3T.

Methods

- Two separate groups of healthy volunteers were imaged using 32-channel head coils on a Siemens 3T (n=5 females, n=4 males, ages 23-49, mean age 29) and a Siemens 7T (n=6 females, ages 23-49, mean age 32) under IRB approval. Three of the female subjects were part of both groups.
- A multi-echo GRE sequence was used to map signal evolution (15 slices, 0.17-0.5 mm gap, 1.5 mm isotropic resolution, FA 60-70°, 3-5 averages, scan time 6-10 min).
- At 3T, 29 echoes covered TE = 3.3-60.0 ms, at 7T 36 echoes covered TE = 2.3-61.1 ms.
- ROI analyses and multi-exponential fitting of ROI-averaged multi-echo GRE data were performed using IDL.
- ROIs were manually selected in the splenium of the corpus callosum (SCC), in a region where fibers ran approximately perpendicular to the magnetic field (B_0), see Figure 1C,D. This was done to avoid variability due to known effects of fiber orientation (relative to B_0 direction) on the signal decay^{2,3}. Surrounding gray matter was used as a reference.

Results

- Complex signal (S) was fitted to a three-component model where i was the imaginary unit, A_k the amplitude, Δf_k the frequency shift, and $R_{2,k}^*$ the relaxation rate.

$$S = A_1 e^{(-R_{2,1}^* + i\Delta f_1)t} + A_2 e^{(-R_{2,2}^* + i\Delta f_2)t} + A_3 e^{(-R_{2,3}^* + i\Delta f_3)t}$$

- Example data showing the goodness of fit at 3T and 7T is shown in Figure 1A,B.
- Values for relative amplitude, R_2^* , and frequency shift were comparable to previous reports of SCC at 7T (Table 1)². Relative amplitude for each component was found to be similarly distributed at 7T and 3T.
- A field dependence was observed for R_2^* and Δf values, with the 3T values being 41-50% and 21-53% lower respectively than the 7T values (Table 1, Figure 2).

B_0 (T)		A_1 (%)	$R_{2,1}^*$ (Hz)	Δf_1 (Hz)	A_2 (%)	$R_{2,2}^*$ (Hz)	Δf_2 (Hz)	A_3 (%)	$R_{2,3}^*$ (Hz)	Δf_3 (Hz)
7	AVG	12.6	149.9	34.1	51.6	39.7	2.7	35.8	22.6	-3.0
	SD	2.8	18.6	4.7	4.4	3.8	0.6	4.3	2.9	0.6
3	AVG	11.1	87.9	16.2	48.7	21.9	1.3	40.1	11.1	-2.4
	SD	1.2	4.3	0.7	1.9	0.8	0.3	1.8	1.4	0.3

Table 1. Three-component fitting of SCC at 7T and 3T. Mean (AVG) and standard deviation (SD) are reported for relative amplitude (A), relaxation rate (R_2^*), and frequency shift (Δf) for each component.

Acknowledgements



National Science Foundation Research Graduate Fellowship
Georgetown University

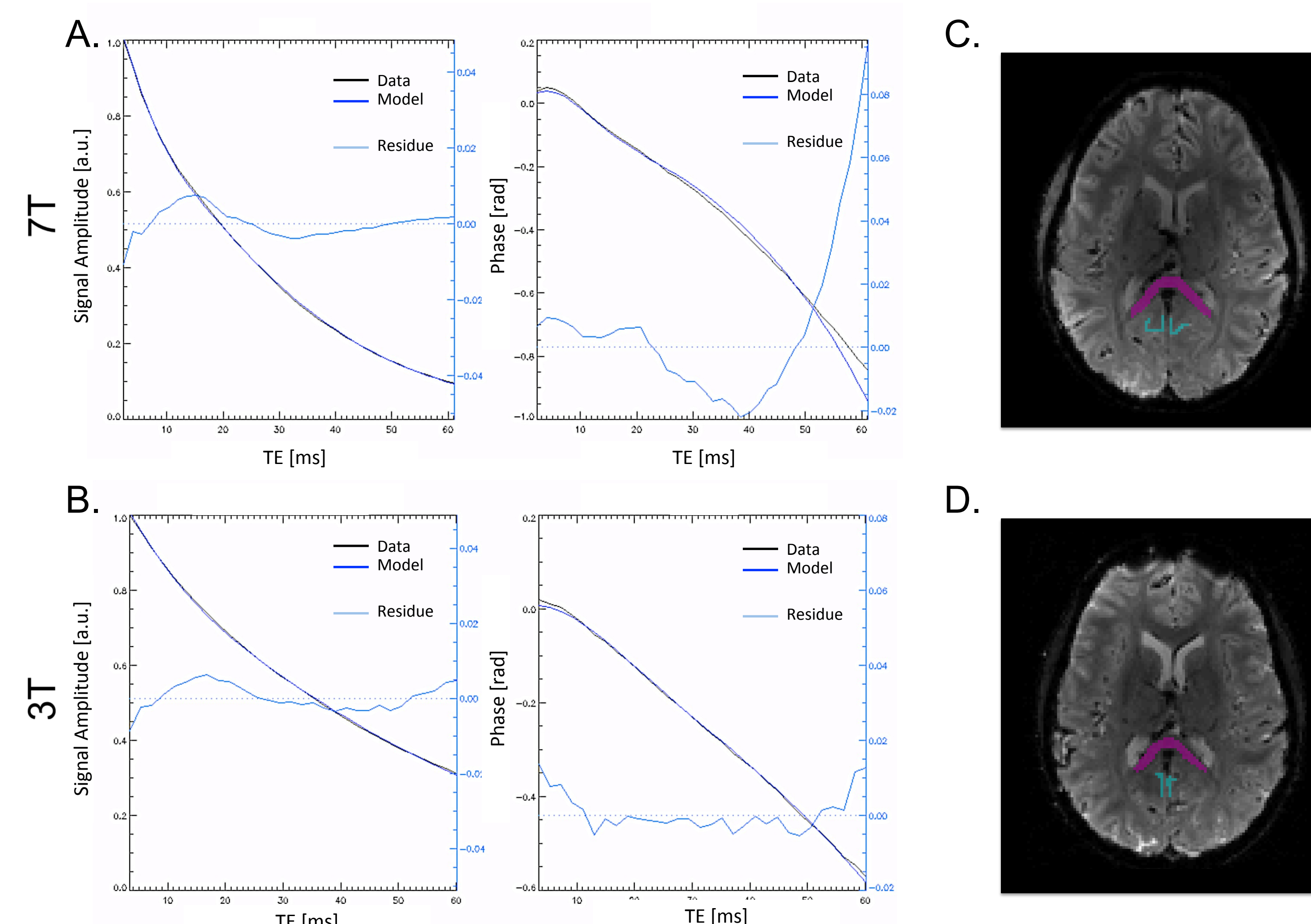


Figure 1. Results of the three-compartment model fit for signal amplitude and phase evolution over echo time in one subject at 7T (A.) and 3T (B.). SCC and gray matter ROI placement in corresponding subject at 7T (C.) and 3T (D.).

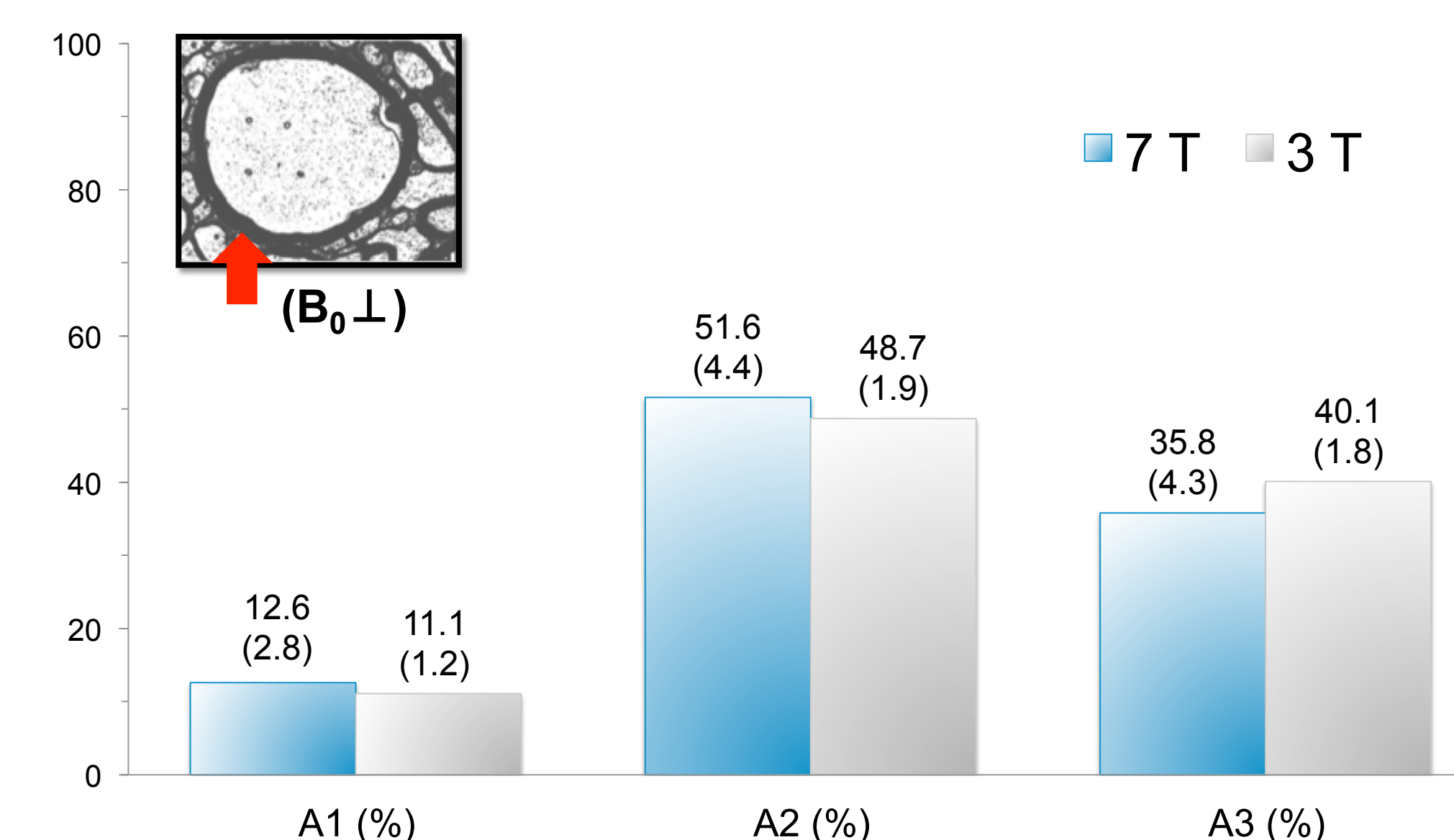


Figure 2: Example of a myelinated axon within SCC (inset). SCC has large axons with thick myelin sheaths that run perpendicular to B_0 , as indicated by the red arrow. The bar graph represents the AVG (SD) amplitude data from Table 1. The relative contributions for myelin water (A_1), interstitial space (A_2), and axonal lumen (A_3) are markedly similar between 7 and 3T.

Conclusions

- The results presented here confirm the previously reported feasibility of separating, in a major fiber bundle, cellular compartment-specific contributions to susceptibility contrast^{1,2}.
- They further indicate that similar findings can be obtained at the more common field strength of 3T.
- This would allow quantification of the myelin water-fraction, and inference of local myelin content, with possible application of studying changes in myelination with disease.
- Because of the reduced susceptibility contrast at 3T, distinction between the cellular compartments may be somewhat compromised, which affects the accuracy of the component fractions. This may be mitigated by reducing the number of free parameters during the fitting process, e.g. by fixing the R_2^* values for the individual components.

References

- van Gelderen P, de Zwart JA, Lee J, et al. Nonexponential T_2 decay in white matter. *Magnetic Res Med*. 2012;67(1):110-117.
- Sati P, van Gelderen P, Silva AC, et al. Micro-compartment specific T_2^* relaxation in the brain. *Neuroimage*. 2013;77:268-278.
- Wharton S and Bowtell R. Fiber orientation-dependent white matter contrast in gradient echo MRI. *PNAS*. 2012; 109(45):18559-18564.



To download this poster please visit:
<http://www.amri.ninds.nih.gov/presentations/2014/ravenep.ismrm.3145.pdf>